Introduction to Power System Protection

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Introduction to Protection

- Power system review
- Protection system purpose
- Protection system components
- Protection system measures
- Types of protective relays
Objectives

• Understand what protective relays are and how the basic types work

• Know the “terms” used in power system protection

• Relate SEL products to their typical applications
Power System Elements

- Generators
- Transformers
- Power Lines
- Buses
- Capacitor Banks
Zones of Protection
Protective Relay Functions

- Detect Faults
  - Short circuits
- Detect abnormal operating conditions
  - Overloads, unbalances, low voltage or frequency
- Control and supervision
  - Automatic reclosing, bus transfer, synch-check
Components of a Protection System
Protective Relaying System

Current Transformers

Circuit Breaker

Voltage Transformers

Relay

Communications Channel

DC Supply
Protection System Elements

- Protective Relays
- Circuit Breakers
- Current and Voltage Transformers
- Communication Channels
- DC Supply System
- Control Cables
Instrument Transformers

- **CT** – Current Transformer
  - Current scaling
  - Isolation from primary voltage

- **VT** – Voltage Transformer
  - Voltage scaling
  - Isolation from primary voltage
Measures Applied to Relays

How do relay engineers evaluate and classify relays; and decide which ones to use?
Protection Operation Classification

- Correct Operation
- Incorrect Operation
  - Failure to trip
  - False tripping
Power System Protection Requirements

- **Measures of Reliability**
  - Dependability – ability of relay to always trip for a fault in its protected zone
  - Security – ability of relay to never trip for a fault outside its protected zone
Power System Protection Requirements

• **Measures of Performance**
  • *Sensitivity* – ability of relay to determine a faulted power system from a normal power system
  • *Selectivity* – ability of a relay to determine what part of the power system is faulted
Power System Protection Requirements

• Measures of Performance (cont.)
  • **Dependability** – ability of relay to always trip for a fault in its protected zone
  • **Security** – ability of relay to never trip for a fault outside its protected zone
  • **Speed** – how fast can the relay determine that there is a fault in its zone
Power System Protection Requirements

- Simplicity
- Economics
  - Protection costs
  - Equipment costs
  - Outage costs
General Relationships

- Higher selectivity allows higher speed
- Dependability is generally proportional to sensitivity and speed
- Security is generally proportional to selectivity
- Higher speed and selectivity generally means higher cost and complexity
Types of Protective Relays
IEEE C37.2 Device Numbers

- 50 – *Instantaneous Overcurrent Relay*
- 51 – *Time Overcurrent Relay*
- 67 – *Directional Overcurrent Relay*
- 21 – *Distance Relay*
- 87 – *Differential Relay*
Overcurrent Relays

- Detect current above normal and trip
- Two types
  - Instantaneous (ANSI Code 50)
  - Inverse Time (ANSI Code 51)
Overcurrent Relay Types

- Instantaneous (50, 50N)
- Time-Delayed (51, 51N)

![Graph showing Inverse Time and Definite Time with IPU and I labels]
Inverse Time OC (ANSI Code 51)

- Works like a fuse
  - Trip **fast** for high overcurrent
  - Trip **slow** for small overcurrent
- Desirable attribute for many protection problems
Application of OC Relays

• Commonly used for:
  • Primary fault protection for radial feeders
  • Backup fault protection for more sophisticated relay schemes
  • Supervisory elements for more sophisticated relay schemes
  • Overload protection
Overcurrent Application

Fast Bus Trip Scheme

Distribution Bus

Trip and Close

Distribution Feeder
Overcurrent Application

- **I_{ABC}**
- Fast Bus Trip Scheme
- Distribution Bus
- 52
Overcurrent Application
Overcurrent Application

Core-Balance CT

\[ I_{ABC} \]

\[ I_N \]

Trip

52
Summary for Overcurrent Relays

<table>
<thead>
<tr>
<th>Measure</th>
<th>Rating</th>
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<tbody>
<tr>
<td>Sensitivity</td>
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Directional Overcurrent Relays

• ANSI Code 67
• Two criteria
  • Determine that current is flowing in a particular direction
  • Detect current above normal and trip
• More selective
How do we determine direction?

- Which way did he go?
- AC current reverses direction every half cycle!
How do we determine direction?

- We need a reference
  - Called a polarizing quantity
- Phase angle of current with respect to voltage for example
Application of Directional Relays

- Twice as selective as 50/51 relays
- Used in applications that need more selectivity such as:
  - Networked lines with fused loads
  - Bus mains and ties
  - Supervisory elements for more sophisticated relay schemes
Directional Relay Application

Reverse Fault (F2)

Forward Fault (F1)
## Summary for Directional Relays

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<tr>
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Distance Relays

• ANSI Code 21
• Determines:
  • Not only the direction of the fault
  • But, also how far away it is
• Set the reach of the relay in ohms (Resistance and Reactance)
• Line has characteristics ohms/mile
  • Measured \( \text{ohms} = \text{distance} \)
Types of Distance Relays

- Two types in general use today
  - Mho (used in the US)
  - Quadrilateral (Common in Europe)
Mho Relay Characteristic
Application of Distance Relays

- Even more selective than 67 relays since they only respond to faults within their reach
- Used where more selectivity is required
  - Networked lines with critical clearing times
Distance Relay Application

- **Zone 1** (Instantaneous)
- **Zone 2** (15-30 cycle delay)
- **Zone 3** (> 30 cycle delay)
Improving Distance Relay Selectivity

• *Distance relays are not accurate enough to reach exactly 100% of the line*

• *Use pilot (communication aided) protection*

• *POTT, PUTT, DCB, DCUB*
Pilot Protection

XMTR = Transmitter

RCVR = Receiver
Pilot Protection

If each end of the line tells the other if the fault is forward or reverse, they can compare notes and determine if the fault is inside the protected zone.
Distance Relay Application (POTT)
Distance Relay Application (DCB)

Figure 1 Example System One-Line Diagram

Local Zone 2
Block Trip Signal (Remote Zone 3)
Trip
# Summary for Distance Relays

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Differential Relays

• ANSI Code 87

• Simple concept:
  • Measure current in vs. current out
  • If they are not equal, then trip

• Operates on the difference in current – not the total current, thus sensitivity is good
Differential Relay Zone

Protected zone is precisely determined by location of CT’s connected to relay
Types of Differential Relays

- Differential Overcurrent
  - Operates on magnitude of difference

- Percent Restrained Differential
  - Difference must be a percentage of the total current
  - Automatically adjusts sensitivity
Types of Differential Relays

- **Line Current Differential**
  - Communicate current at remote and of each zone through communications channel
- **High Impedance Bus Differential**
Differential Relay Application

HV

800/1

3

100/5 (REF)

2000/5

3

LV

SEL-787 TRANSFORMER PROTECION RELAY
Differential Relay Application
Line Current Differential

Exchange of current data across high speed channel

Relays

Communications Channel

Relays

T

R

T

R
Differential Protection is Even Used in the Home!

- **GFCI (Ground Fault Circuit Interrupter)**
  - Compare the current going to an appliance to the current returning
  - Trips for a very small difference
  - High sensitivity to keep you safe
Application of Differential Relays

- Applied anywhere that high speed, high sensitivity, and high selectivity is required:
  - Transformers
  - Generators
  - Bus Sections
  - Lines
# Summary for Differential Relays

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Summary

- There are four main relay types for detecting faults
  - 50/51, 67, 21, 87
- We decide on which types of relays to use based upon several factors
  - Sensitivity, selectivity, speed, cost, simplicity
- There are two measures for reliability
  - Dependability, security
Any Questions?